

Contemporary utilization and outcomes of intra-aortic balloon counterpulsation in acute myocardial infarction: the benchmark registry

STONE, Gregg W, *et al.*

Abstract

We sought to examine contemporary utilization patterns and clinical outcomes in patients with acute myocardial infarction (AMI) requiring intra-aortic balloon pump (IABP) counterpulsation.

Reference

STONE, Gregg W, *et al.* Contemporary utilization and outcomes of intra-aortic balloon counterpulsation in acute myocardial infarction: the benchmark registry. *Journal of the American College of Cardiology*, 2003, vol. 41, no. 11, p. 1940-5

PMID : 12798561

DOI : 10.1016/S0735-1097(03)00400-5

Available at:

<http://archive-ouverte.unige.ch/unige:45480>

Disclaimer: layout of this document may differ from the published version.



UNIVERSITÉ
DE GENÈVE

Acute Myocardial Ischemia/Infarction

Contemporary Utilization and Outcomes of Intra-Aortic Balloon Counterpulsation in Acute Myocardial Infarction

The Benchmark Registry

Gregg W. Stone, MD, FACC,* E. Magnus Ohman, MD, FACC,† Michael F. Miller, PhD,‡

Debra L. Joseph, BSN,§ Jan T. Christenson, MD, FECTS,|| Marc Cohen, MD, FACC,¶

Philip M. Urban, MD, FACC,# Ramachandra C. Reddy, MD, FACC,**

Robert J. Freedman, MD, FACC,†† Karen L. Staman, MS,‡‡ James J. Ferguson III, MD, FACC§§

New York and Brooklyn, New York; Chapel Hill and Durham, North Carolina; Langhorne and Philadelphia, Pennsylvania; Fairfield, New Jersey; Geneva, Switzerland; Alexandria, Louisiana; and Houston, Texas

OBJECTIVES	We sought to examine contemporary utilization patterns and clinical outcomes in patients with acute myocardial infarction (AMI) requiring intra-aortic balloon pump (IABP) counterpulsation.
BACKGROUND	Despite increasing experience with and broadened indications for intra-aortic counterpulsation, the current indications, associated complications, and clinical outcomes of IABP use in AMI are unknown.
METHODS	Between June 1996 and August 2001, data were prospectively collected from 22,663 consecutive patients treated with aortic counterpulsation at 250 medical centers worldwide; 5,495 of these patients had AMI.
RESULTS	Placement of an IABP in AMI patients was most frequently indicated for cardiogenic shock (27.3%), hemodynamic support during catheterization and/or angioplasty (27.2%) or prior to high-risk surgery (11.2%), mechanical complications of AMI (11.7%), and refractory post-myocardial infarction unstable angina (10.0%). Balloon insertions were successful in 97.7% of patients. Diagnostic catheterization was performed in 96% of patients, and 83% underwent coronary revascularization before hospital discharge. The in-hospital mortality rate was 20.0% (38.7% in patients with shock) and varied markedly by indication and use of revascularization procedures. Major IABP complications occurred in only 2.7% of patients, despite median use for three days, and early IABP discontinuation was required in only 2.1% of patients.
CONCLUSIONS	With contemporary advances in device technology, insertion technique, and operator experience, IABP counterpulsation may be successfully employed for a wide variety of conditions in the AMI setting, providing significant hemodynamic support with rare major complications in a high-risk patient population. (J Am Coll Cardiol 2003;41:1940-5) © 2003 by the American College of Cardiology Foundation

Following its introduction, intra-aortic balloon pump (IABP) counterpulsation was principally applied to stabilize medical and surgical patients with hemodynamic collapse and to increase myocardial oxygen supply as a last resort in

patients with incipient cardiac arrest (1,2). Although the IABP is still widely used in patients with cardiogenic shock, accumulating clinical experience and trial data have resulted in significant expansion of the indications for aortic counterpulsation in patients with acute myocardial infarction (AMI) (3). Evidence may be cited supporting the use of the IABP in AMI patients with ventricular septal rupture and acute mitral insufficiency (4,5), post-infarct angina (6), recalcitrant ventricular arrhythmias (7), and progressive

See page 1946

heart failure despite medical therapy (8). In patients with AMI, the IABP may improve cardiac performance and hemodynamic measures while the ischemic myocardium recovers (9), decrease the incidence of recurrent ischemia (10,11) and infarct-related artery reocclusion after reperfu-

From the *Cardiovascular Research Foundation and Lenox Hill Hospital, New York, New York; †University of North Carolina, Chapel Hill, North Carolina; ‡M. F. Miller Statistical Services, Langhorne, Pennsylvania; §Datascope Corp., Fairfield, New Jersey; ||University of Geneva Hospital, Geneva, Switzerland; ¶Hahnemann University Hospital, Philadelphia, Pennsylvania; #Hôpital de la Tour, Geneva, Switzerland; **State University of New York Health Science Center, Brooklyn, New York; ††St. Francis Cabrini Medical Center, Alexandria, Louisiana; ‡‡Duke Clinical Research Institute, Durham, North Carolina; and §§Texas Heart Institute, Houston, Texas. The Benchmark Counterpulsation Outcomes Registry was partly supported by Datascope Corp. Ms. Joseph is an employee of Datascope, a manufacturer of intra-aortic balloon pumps and the sponsor of the Benchmark Registry. Dr. Miller is a statistical consultant to Datascope. Several authors (Drs. Stone, Ohman, Christenson, Cohen, Urban, Reddy, Freedman, and Ferguson) have received small consultation fees in relation to the registry.

Manuscript received April 15, 2002; revised manuscript received September 4, 2002, accepted September 20, 2002.

Abbreviations and Acronyms

AMI	= acute myocardial infarction
CABG	= coronary artery bypass grafting
IABP	= intra-aortic balloon pump
LMCA	= left main coronary artery
SHOCK	= SHow we emergently revascularize Occluded Coronaries for cardiogenic shock?

sion therapy (12,13), improve survival when used in conjunction with thrombolytic therapy compared with thrombolytic therapy alone (14,15), and enhance rescue angioplasty for failed thrombolysis (16).

Despite the increasing experience with and broadened indications for aortic counterpulsation, the current utilization patterns, associated complications, and clinical outcomes of patients with AMI in whom an IABP is required are unknown. As previously reported, the Benchmark Counterpulsation Outcomes Registry was developed to examine the patient profiles, device indications, hemodynamic measures, clinical outcomes, and complications associated with IABP in a broad cross section of patients (17). The present report summarizes contemporary usage patterns and outcomes in patients with AMI requiring IABP counterpulsation from this large global registry.

METHODS

The details of the ongoing Benchmark Counterpulsation Outcomes Registry, the participating sites, study organization, and methodology for data collection and analysis have previously been described (17). In brief, the Benchmark Registry collects detailed clinical and device level data in consecutive patients receiving an IABP on an institutional level and affords individual hospitals the ability to compare and contrast outcomes and usage patterns to the database as a whole. The current analysis includes all consecutive patients with AMI in participating institutions in whom an IABP was placed between June 1996 (or the time of institution initiation into the registry) and August 2001. Concomitant medications and adjunctive procedures were left to the discretion of the treating physician.

End points, definitions, and statistical methods. The four principal clinical end points were ischemia, bleeding, IABP failure, and in-hospital mortality. Major limb ischemia was defined as a loss of pulse or sensation, or abnormal limb temperature or pallor requiring surgical intervention. Minor ischemia involved decreased arterial flow, as manifested by a diminished pulse that resolved with balloon removal, not otherwise resulting in impairment of organ function. Severe bleeding was defined as requirement of blood transfusion or surgical intervention, or association with hemodynamic compromise. Minor hematoma and oozing from a puncture site not requiring blood transfusion or surgical intervention was defined as nonsevere bleeding. Failure of the IABP was defined as poor augmentation,

inability to deploy, or any IABP leak suggested by blood inside the catheter tubing, gas loss, or catheter alarm. All-cause hospital mortality was recorded as mortality occurring from any cause during IABP use or after IABP removal. Mortality directly related to IABP was also tabulated. A major IABP-related complication was defined as major limb ischemia, severe bleeding, IABP leak, or mortality directly attributed to IABP. Components of the clinical diagnosis of AMI, as well as infarct location, were not prespecified but defined on-site using standard, local definitions. Cardiogenic shock, however, was prospectively defined as systolic blood pressure ≤ 90 mm Hg for ≥ 1 h (or necessitating intravenous pressors of IABP for support), associated with signs of systemic hypoperfusion (cool, clammy skin, urine output < 30 ml/h, or decreased level of consciousness) or a cardiac index < 2.0 l/min/m², secondary to cardiac dysfunction and not responsive to volume replacement alone.

Descriptive summaries included frequency and percent distributions for the categorical variables, and the sample mean value \pm SD for continuous variables. The paired *t* test was used to compare the effect of IABP placement on hemodynamic measures. Stepwise logistic regression was performed to determine the independent correlates of in-hospital mortality, considering age, gender, diabetes mellitus, previous MI, previous coronary artery bypass graft surgery (CABG), peripheral vascular disease, left main coronary artery (LMCA) involvement, cardiogenic shock, and performance of percutaneous or surgical revascularization in the model. All variables that were significant by univariate analysis (likelihood ratio chi-square test), with a *p* value < 0.10 , were included in the multivariate model. All analyses were performed using SAS statistical software, version 8 (SAS Institute, Cary, North Carolina). The registry was validated by three audits (two independent and one internal), which demonstrated a high degree of accuracy ($> 95\%$ accuracy for check-box items and $> 90\%$ accuracy for dates). The largest external audit was performed by StatTrade Inc. (Morrisville, Pennsylvania), and involved 485 records (20.7%) entered in 1999.

RESULTS

Clinical features and indications. Between June 1996 and August 2001, 22,663 patients received an IABP at 250 centers (185 U.S. centers and 65 centers outside the U.S.); AMI was the principal diagnosis in 5,495 (24%). The mean age of the AMI population was 65.0 ± 12.3 years (range 20 to 100 years); 34% were women. Twenty-six percent of patients had diabetes mellitus, 25% had previous MI, 8% had previous CABG, and 9% had peripheral vascular disease. Of patients undergoing cardiac catheterization, 59% had triple-vessel disease and 16% had LMCA involvement. The mean ejection fraction was $36.5 \pm 14.3\%$. As seen in Table 1, approximately one-half of the patients with AMI required an IABP for cardiogenic shock or hemodynamic

Table 1. Principal Indications for Intra-Aortic Balloon Pump Use in 5,495 Patients With AMI

Cardiogenic shock	27.3%
Support for high-risk catheterization and angioplasty	27.2%
Mechanical complications of AMI (VSD and PMR)	11.7%
Pre-operative support for high-risk cardiac surgery	11.2%
Refractory post-MI unstable angina	10.0%
Weaning from cardiopulmonary bypass	4.8%
Refractory left ventricular failure	4.5%
Refractory ventricular arrhythmias	1.3%
Intra-operative support during surgery	0.5%
Other or indication not recorded	1.5%

AMI = acute myocardial infarction; MI = myocardial infarction; PMR = papillary muscle rupture; VSD = ventricular septal defect.

support during or after cardiac catheterization or percutaneous intervention, whereas a variety of alternative reasons were present in the other half of patients.

Performance and complications of IABP. The IABP was inserted percutaneously in 98% of patients and by femoral artery cutdown in 2%. A 9.5F system was utilized in 65% of patients and an 8F system in 35%. A sheath was employed in 80% of patients, whereas in 20%, insertion was sheathless. Of the balloon insertions, 2.3% were unsuccessful due to a balloon leak, poor balloon inflation, poor augmentation or difficulties associated with balloon insertion. As shown in Table 2, IABP placement resulted in significant reductions in systolic and diastolic arterial pressures, with no impact on heart rate. The mean duration of IABP in the overall registry cohort was 3.2 ± 2.2 days (median 3 days, range 1 to 42 days).

One or more complications of IABP therapy occurred in 8.1% of patients (Table 3), although major complications (severe limb ischemia, severe bleeding, balloon leak, or death directly due to IABP insertion or failure) occurred in only 2.7% of cases. Considering the five most common indications for aortic counterpulsation, the occurrence of major IABP-related complications did not significantly vary (cardiogenic shock in 2.9%, support for high-risk catheterization and angioplasty in 2.7%, surgery in 2.6%, mechanical complications of AMI in 2.2%, and refractory unstable angina in 3.1%; $p = 0.57$). Death was directly attributed to the IABP in only three patients (0.05%).

Angiography and revascularization procedures. Angiography was performed in 5,348 patients (97.3%) during the index hospitalization, and 4,476 patients (81.5%) underwent coronary revascularization procedures, split approxi-

Table 2. Effect of IABP Placement on Hemodynamic Measures

	Pre-IABP	Post-IABP	p Value
Systolic blood pressure (mm Hg)	109 \pm 28	108 \pm 25	<0.001
Diastolic blood pressure (mm Hg)	65 \pm 17	62 \pm 17	<0.001
Augmented diastolic blood pressure (mm Hg)	—	122 \pm 29	—
Mean arterial pressure (mm Hg)	82 \pm 21	87 \pm 21	<0.001
Heart rate (beats/min)	89 \pm 24	90 \pm 23	0.59

Data are presented as the mean value \pm SD.

IABP = intra-aortic balloon pump.

Table 3. Failure and Complications of the IABP (n = 5,495)

Complications	
Any access-site bleeding	4.3%
Severe access-site bleeding	1.4%
Any limb ischemia	2.3%
Major limb ischemia	0.5%
Amputation	0.1%
Transfusion	1.4%
Vascular surgery	0.7%
Infection	0.1%
Deep venous thrombosis	0.1%
Superficial vein thrombosis	0.1%
Stroke	0.1%
Bowel, renal, or spinal cord infarction	0.1%
IABP-related mortality	0.05%
IABP failure	
Any	2.3%
IABP leak	0.8%
Poor inflation	0.6%
Difficult insertion	0.1%
Poor augmentation	1.1%
Premature IABP removal	2.1%
IABP replaced	0.5%

IABP = intra-aortic balloon pump.

mately equally between percutaneous intervention (41.5%) and CABG (40.0%). An additional 192 patients (3.5%) underwent additional surgical procedures without revascularization. A detailed list of the percutaneous and surgical procedures performed in patients with AMI receiving an IABP appears in Table 4. The rates of major IABP-related complications were similar among patients undergoing angioplasty (2.8%), surgery (2.6%), or conservative management with or without angiography (2.7%).

In-hospital mortality. The mean duration of hospitalization was 11.5 ± 9.9 days (range 1 to 96 days). In-hospital death occurred in 1,098 (20%) of 5,495 patients with AMI in whom an IABP was placed; 581 (53%) of the 1,098 deaths occurred with the IABP in situ, whereas the remainder occurred after the device had been removed. As seen in Figure 1, in-hospital mortality ranged from 6.4% in patients

Table 4. Percutaneous and Surgical Procedures in Patients With Acute Myocardial Infarction Receiving an Intra-Aortic Balloon Pump*

Percutaneous (n = 2,282)	
Balloon angioplasty	100%
Stent	79.5%
Atherectomy	2.3%
Laser	0.1%
Other	3.3%
Surgical (n = 2,388)	
Bypass graft surgery	92.0%
Minimally invasive bypass grafting	0.9%
Mitral valve repair or replacement	9.1%
Aortic valve replacement	2.0%
Ventricular assist device	1.5%
Ventricular septal defect repair	0.5%
Orthotopic cardiac transplantation	0.4%
Transmyocardial revascularization	0.3%
Other	3.1%

*More than one procedure per patient may have been performed.

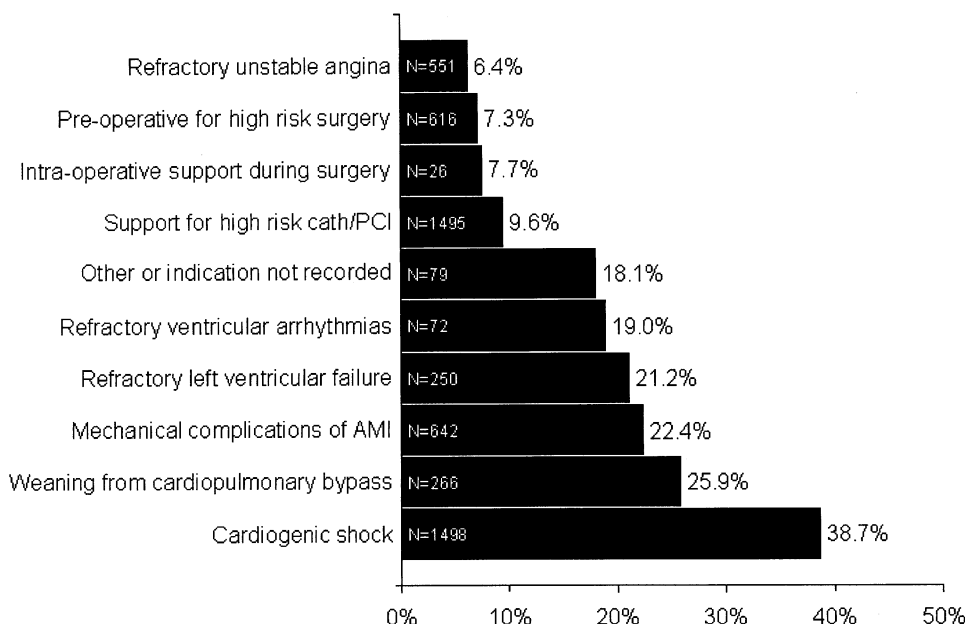


Figure 1. In-hospital mortality of 5,495 patients with acute myocardial infarction (AMI) requiring intra-aortic balloon pump counterpulsation, stratified by principal usage indication. PCI = percutaneous coronary intervention.

in whom the IABP was placed for refractory unstable angina to 38.7% in patients requiring aortic counterpulsation for cardiogenic shock. In-hospital mortality in patients with an IABP also varied considerably, based on the use of revascularization procedures, ranging from 12.5% in patients undergoing CABG to 53.7% in those managed conservatively (Fig. 2). Independent predictors of mortality in patients with AMI requiring IABP placement are shown in Table 5.

DISCUSSION

The principal findings of this study are: 1) IABP counterpulsation is used in patients with AMI for a variety of purposes that extend beyond traditional indications; 2)

severe IABP-related complications are infrequent in patients with AMI, even in those in cardiogenic shock; and 3) in-hospital mortality rates in this high-risk population vary considerably, based on IABP indication and use of revascularization procedures.

Indications for IABP use in AMI. According to the 1999 Task Force on Practice Guidelines of the American Heart Association and American College of Cardiology (18), class I indications for IABP use in AMI include: 1) cardiogenic shock as a stabilizing measure for angiography and prompt revascularization; 2) acute mitral regurgitation or ventricular septal defect complicating AMI as stabilizing therapy for angiography and repair/revascularization; 3) recurrent, intractable ventricular arrhythmias with hemodynamic insta-

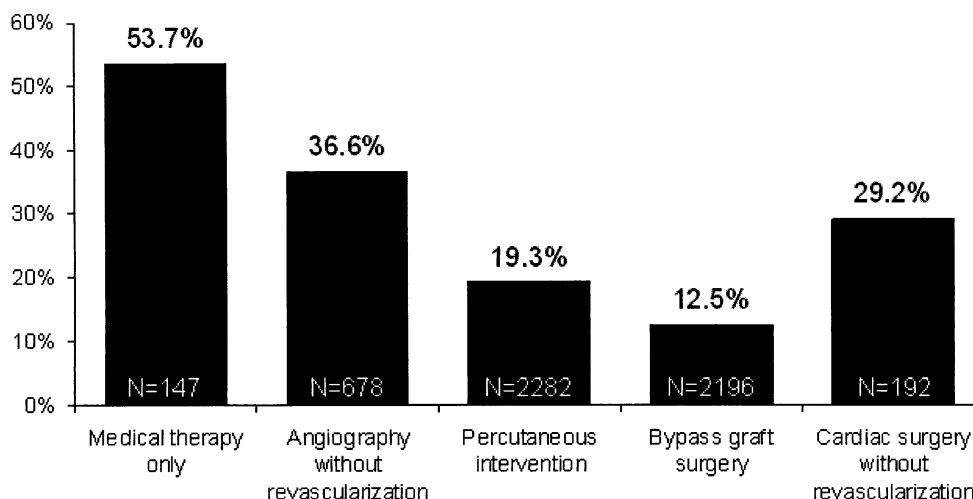


Figure 2. In-hospital mortality stratified by the performance of angiography and percutaneous or surgical coronary revascularization.

Table 5. Independent Correlates of In-Hospital Mortality by Logistic Regression Analysis

	Multivariate Odds Ratio (95% CI)	p Value
Cardiogenic shock	3.95 (3.41–4.58)	<0.0001
Age >75 yrs	2.36 (2.02–2.77)	<0.0001
Previous myocardial infarction	1.52 (1.29–1.79)	<0.0001
Female gender	1.47 (1.26–1.71)	<0.0001
Previous bypass surgery	1.42 (1.12–1.81)	0.004
Peripheral vascular disease	1.29 (1.03–1.63)	0.03
Diabetes mellitus	1.18 (1.00–1.39)	0.0497
Performance of percutaneous or surgical revascularization	0.38 (0.33–0.45)	<0.0001

CI = confidence interval.

bility; and 4) refractory post-myocardial infarction angina as a bridge to angiography and revascularization. In the present series, these four categories comprised only ~50% of the indications for IABP use in patients with AMI. Significant numbers of patients also received an IABP prophylactically before angiography, percutaneous intervention, or surgical revascularization, prompted by the frequent presence in this population of prognostically adverse features such as depressed left ventricular function and significant LMCA or triple-vessel disease. Although the utility of IABP counterpulsation has not been established in these settings by randomized clinical trials, the data from this large series provide insight into contemporary usage patterns of IABP counterpulsation and associated outcomes for these clinical situations.

Performance and complications of IABP counterpulsation. Placement of an IABP resulted in notable augmentation of diastolic blood pressure and a significant though small reduction in systolic blood pressure, with no change in heart rate. These findings suggest that the major hemodynamic and clinical benefits of IABP counterpulsation will be realized in patients with systemic hypotension, with relatively little reduction in afterload or myocardial oxygen demand. A limitation of this study, however, is that right heart catheterization was not routinely performed before and after IABP insertion (and the data were not recorded), thus potentially masking any possible benefit of preload reduction lowering the pulmonary capillary wedge pressure.

A unique finding of this study is in regard to the analysis of successful IABP placement: in only 2.2% of patients could IABP counterpulsation not be established due to balloon leak, poor inflation, poor augmentation, or insertion difficulty. Moreover, despite earlier reports documenting high rates of adverse events secondary to IABP usage (3,19–21), major IABP-related complications in patients with AMI in this large, contemporary series were relatively infrequent (2.7%). As a result, only 2.1% of patients required premature discontinuation of the device. These findings represent real-world documentation that advances such as percutaneous insertion, smaller catheter diameter, and appropriate use of adjunctive pharmacology have considerably reduced the incidence of serious vascular compli-

cations (19–27). Thus, it is reassuring that the hemodynamic benefits of IABP may be realized in this high-risk patient cohort with relatively low risk.

Use of revascularization procedures and mortality. The in-hospital mortality of patients with AMI requiring an IABP varied greatly with the principal usage indication and performance of coronary revascularization. The value of an early revascularization strategy after IABP placement in patients with cardiogenic shock has recently been clearly demonstrated (28,29) and appears to currently be the predominant intent at most centers, as angiography was performed in more than 97% of AMI patients in the Benchmark Registry (with revascularization in nearly 82%). The mortality of patients with AMI requiring IABP support was greatest in those in whom angiography and revascularization were not performed, consistent with previous small, randomized trials that found no survival benefit of IABP counterpulsation in patients with AMI managed conservatively (30,31). Indeed, in the present series, the performance of coronary revascularization was a powerful independent predictor of survival by multivariate analysis. Moreover, the 38.7% rate of in-hospital mortality in the 1,498 patients with cardiogenic shock in the current report is similar to the 46.7% 30-day mortality rate in 152 patients assigned to the invasive arm of the SHould we emergently revascularize Occluded Coronaries for cardiogenic shock? (SHOCK) trial (28). In both studies, >80% of patients were revascularized. Finally, given its size and broad geographic representation, the current registry may be used to “benchmark” in-hospital mortality rates of patients with AMI requiring IABP counterpulsation for conditions other than shock. Indeed, comparative outcomes data are regularly given to the individual sites participating in the Benchmark Registry to facilitate quality-control implementation.

Study limitations. The present study is a large-scale, voluntary prospective registry and, as such, has the limitations inherent in all registries, including selection (reporting) bias for patient recruitment and a lack of documentation of all relevant variables related to outcome. Site-to-site variations in personnel and resources allocated to the registry cannot be excluded, nor can regional, local, and individual differences in patients and practice patterns. To the extent possible, some of these concerns may be alleviated by the prospective nature of the registry, the results of the validation audits demonstrating high accuracy and compliance, and the use of multivariate analysis to correct for differences in patient characteristics. The Benchmark Counterpulsation Outcomes Registry, representing the largest contemporary experience with IABP usage, therefore, should be viewed as complementary to well-designed, randomized, controlled clinical trials. However, no adequately powered, controlled trial has ever been performed to demonstrate whether IABP counterpulsation does indeed improve clinical outcomes and/or reduce mortality in patients with AMI and shock undergoing reperfusion therapy

or in a subset of such patients. As the entry criteria for the Benchmark Registry required IABP usage, data from this study cannot be used to support such a conclusion. Frequency and outcomes data are also not available for patients in whom IABP usage might have been beneficial, but in whom placement of the device was contraindicated because of peripheral vascular disease, aortic insufficiency, or other adverse conditions. Finally, as right heart catheterization data were not routinely collected in this study, no statements can be made regarding the efficacy of IABP to reduce preload and afterload in the AMI setting, either in patients with or without cardiogenic shock.

Reprint requests and correspondence: Dr. Gregg W. Stone, Cardiovascular Research Foundation, 55 East 59th Street, 6th Floor, New York, New York 10022. E-mail: gstone@crf.org.

REFERENCES

- Beckman CB, Romero LH, Shatney CH, Nicoloff DM, Lillehei RC, Dietzman RH. Clinical comparison of the intra-aortic balloon pump and external counterpulsation for cardiogenic shock. *Trans Am Soc Artif Intern Organs* 1973;19:414–8.
- Lefemine AA, Kosowsky B, Madoff I, Black H, Lewis M. Results and complications of intra-aortic balloon pumping in surgical and medical patients. *Am J Cardiol* 1977;40:416–20.
- Mahaffey KW, Kruse KR, Ohman EM. Perspectives on the use of intra-aortic balloon counterpulsation in the 1990s. In: Topol EJ, editor. *Textbook of Interventional Cardiology, Update Series, Update no. 21*. Philadelphia, PA: W.B. Saunders, 1996:303–20.
- Estrada-Quintero T, Uretsky BF, Murali S, Hardesty RL. Prolonged intra-aortic balloon support for septal rupture after myocardial infarction. *Ann Thorac Surg* 1992;53:335–7.
- Mueller HS. Role of intra-aortic counterpulsation in cardiogenic shock and acute myocardial infarction. *Cardiology* 1994;84:168–74.
- Gold HK, Leinbach RC, Sanders CA, Buckley MJ, Mundth ED, Austen WG. Intra-aortic balloon pumping for control of recurrent myocardial ischemia. *Circulation* 1973;47:1197–203.
- Fotopoulos GD, Mason MJ, Walker S, et al. Stabilisation of medically refractory ventricular arrhythmias by intra-aortic balloon counterpulsation. *Heart* 1999;82:96–100.
- Hagemeyer F, Laird JD, Haalebos MM, Hugenholtz PG. Effectiveness of intra-aortic balloon pumping without cardiac surgery for patients with severe heart failure secondary to a recent myocardial infarction. *Am J Cardiol* 1977;40:951–6.
- Braunwald E, Kloner RA. The stunned myocardium: prolonged, postischemic ventricular dysfunction. *Circulation* 1982;66:1146–9.
- Stone GW, Marsalese D, Brodie BR, et al., the Second Primary Angioplasty in Myocardial Infarction (PAMI-II) Trial Investigators. A prospective, randomized evaluation of prophylactic intra-aortic balloon counterpulsation in high risk patients with acute myocardial infarction treated with primary angioplasty. *J Am Coll Cardiol* 1997;29:1459–67.
- Ohman EM, George BS, White CJ, et al., the Randomized IABP Study Group. Use of aortic counterpulsation to improve sustained coronary artery patency during acute myocardial infarction: results of a randomized trial. *Circulation* 1994;90:792–9.
- Ohman EM, Califf RM, George BS, et al., the Thrombolysis and Angioplasty in Myocardial Infarction (TAMI) Study Group. The use of intra-aortic balloon pumping as an adjunct to reperfusion therapy in acute myocardial infarction. *Am Heart J* 1991;121:895–901.
- Ishihara M, Sato H, Tateishi H, Uchida T, Dote K. Intra-aortic balloon pumping as the postangioplasty strategy in acute myocardial infarction. *Am Heart J* 1991;122:385–9.
- Sanborn TA, Sleeper LA, Bates ER, et al. Impact of thrombolysis, intra-aortic balloon pump counterpulsation, and their combination in cardiogenic shock complicating acute myocardial infarction: a report from the SHOCK Trial Registry. *J Am Coll Cardiol* 2000;36:1123–9.
- Barron HV, Every NR, Parsons LS, et al. The use of intra-aortic balloon counterpulsation in patients with cardiogenic shock complicating acute myocardial infarction: data from the National Registry of Myocardial Infarction-2. *Am Heart J* 2001;141:933–9.
- Ishihara M, Sato H, Tateishi H, et al. Intra-aortic balloon pumping as adjunctive therapy to rescue coronary angioplasty after failed thrombolysis in anterior wall acute myocardial infarction. *Am J Cardiol* 1995;76:73–5.
- Ferguson JJ, Cohen M, Freedman RJ, et al. The current practice of intra-aortic balloon counterpulsation: results from the Benchmark Registry. *J Am Coll Cardiol* 2001;38:1456–62.
- Ryan TJ, Antman EM, Brooks NH, et al. 1999 Update: ACC/AHA guidelines for the management of patients with acute myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Acute Myocardial Infarction). *J Am Coll Cardiol* 1999;34:890–911.
- Alderman JD, Gabliani GI, McCabe CH, et al. Incidence and management of limb ischemia with percutaneous wire-guided intra-aortic balloon catheters. *J Am Coll Cardiol* 1987;9:524–30.
- Iverson LI, Herfindahl G, Ecker RR, et al. Vascular complications of intra-aortic balloon counterpulsation. *Am J Surg* 1987;154:99–103.
- Skillman JJ, Ducksoo K, Baim DS. Vascular complications of percutaneous femoral cardiac interventions: incidence and operative repair. *Arch Surg* 1988;123:1207–12.
- Elтчchaninoff H, Dimas AP, Whitlow PL. Complications associated with percutaneous placement and use of intra-aortic balloon counterpulsation. *Am J Cardiol* 1993;71:328–32.
- Nash IS, Lorell BH, Fishman BF, Baim DS, Donahue C, Diver DJ. A new technique for sheathless percutaneous intra-aortic balloon catheter insertion. *Cathet Cardiovasc Diagn* 1991;23:57–60.
- Tatar H, Cicek S, Demirkilic U, et al. Vascular complications of intra-aortic balloon pumping: unsheathed versus sheathed insertion. *Ann Thorac Surg* 1993;55:1518–21.
- Winters KJ, Smith SC, Cohen M, Kopistansky C, McBride R. Reduction in ischemic vascular complications with a hydrophilic-coated intra-aortic balloon catheter. *Cathet Cardiovasc Intervent* 1999;46:357–62.
- Arafa OE, Pedersen TH, Svennevig JL, Fosse E, Geiran OR. Vascular complications of the intra-aortic balloon pump in patients undergoing open heart operations: 15-year experience. *Ann Thorac Surg* 1999;67:645–51.
- Busch T, Sirbu H, Zenker D, Dalichau H. Vascular complications related to intra-aortic balloon counterpulsation: an analysis of ten years experience. *Thorac Cardiovasc Surg* 1997;45:55–9.
- Hochman JS, Sleeper LA, Webb JG, et al., the SHould we emergently revascularize Occluded Coronaries for cardiogenic shock? (SHOCK) Investigators. Early revascularization in acute myocardial infarction complicated by cardiogenic shock. *N Engl J Med* 1999;341:625–34.
- Hochman JS, Sleeper LA, White HD, et al. One-year survival following early revascularization for cardiogenic shock. *JAMA* 2001;285:190–2.
- O'Rourke MF, Norris RM, Campbell TJ, Chang VP, Sammel NL. Randomized controlled trial of intra-aortic balloon counterpulsation in early myocardial infarction with acute heart failure. *Am J Cardiol* 1981;47:815–20.
- Flaherty JT, Becker LC, Weiss JL, et al. Results of a randomized prospective trial of intra-aortic balloon counterpulsation and intravenous nitroglycerin in patients with acute myocardial infarction. *J Am Coll Cardiol* 1985;6:434–46.